INTRODUCTION TO IONIC AND COVALENT BONDING

IB Chemistry

Topic 04 - Bonding

What type of bond does each of the following molecules demonstrate?

- H_2O
- $NaCl$
- F_2
- CaF_2
- NH_3
- C_2H_4
- $MgBr_2$

What do you know?

Molecular Interactions

- Inter-molecular Forces
  - Interaction between molecules that hold it together in a network.
- Intra-molecular Forces
  - Forces that hold groups of atoms together and make them function as a unit

Intra-molecular Forces: Bonding

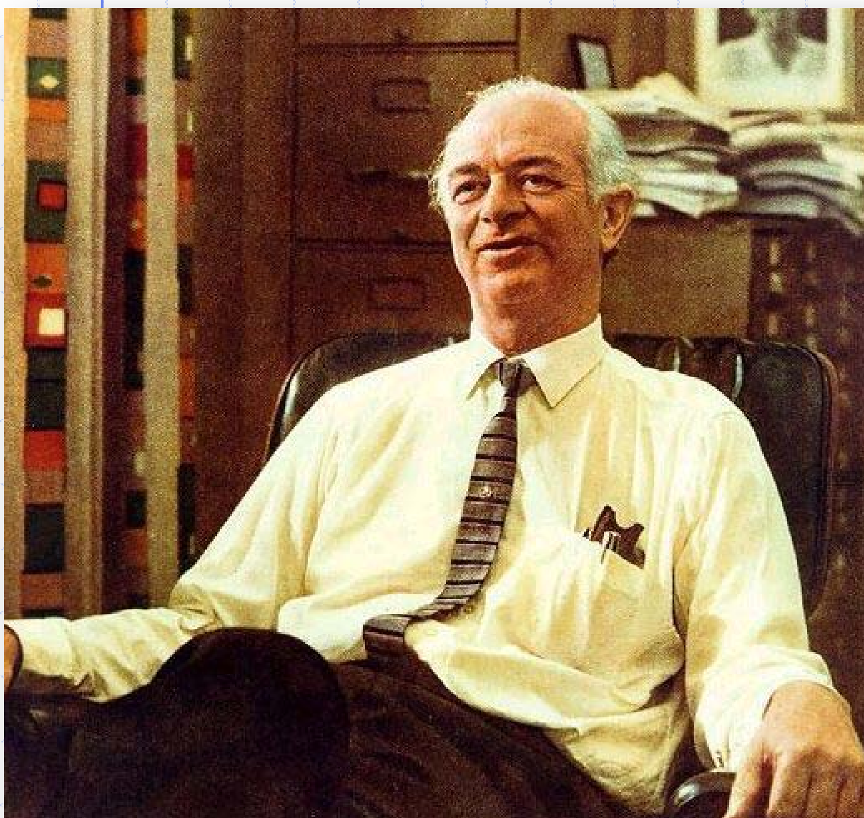
- Forces that hold groups of atoms together and make them function as a unit.
  - Ionic bonds – transfer of electrons
  - Covalent bonds – sharing of electrons
  - Molecular Bonding

Review: Why do atoms bond?

- To satisfy the octet rule?
  - Yes, but to be more specific, atoms share electrons in order to complete their outer electron shell making them more stable as they are then in a lower state of energy.
- But how do we know what type of bonding will occur between two atoms?

Bonding - Ionic or Covalent

How can we determine how two elements will form a bond?



Linus Pauling
1901 - 1994

Electronegativity

The ability or affinity of an atom to attract toward itself the electrons in a chemical bond.

Table of Electronegativities

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
H 2.1																
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5
Cs 0.8	Ba 0.9	La* 1.1	Hf 1.3	Ta 1.5	W 2.4	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.8	Bi 1.9	Po 2.0	At 2.2
Fr 0.7	Ra 0.9	Ac† 1.1														

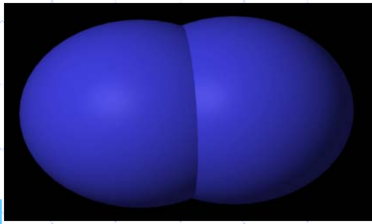
- below 1.0
- 1.0–1.4
- 1.5–1.9
- 2.0–2.4
- 2.5–2.9
- 3.0–4.0

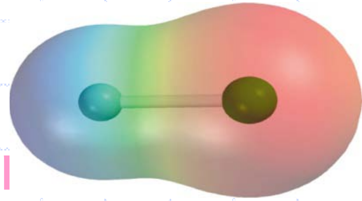
*Lanthanides: 1.1–1.3

†Actinides: 1.3–1.5

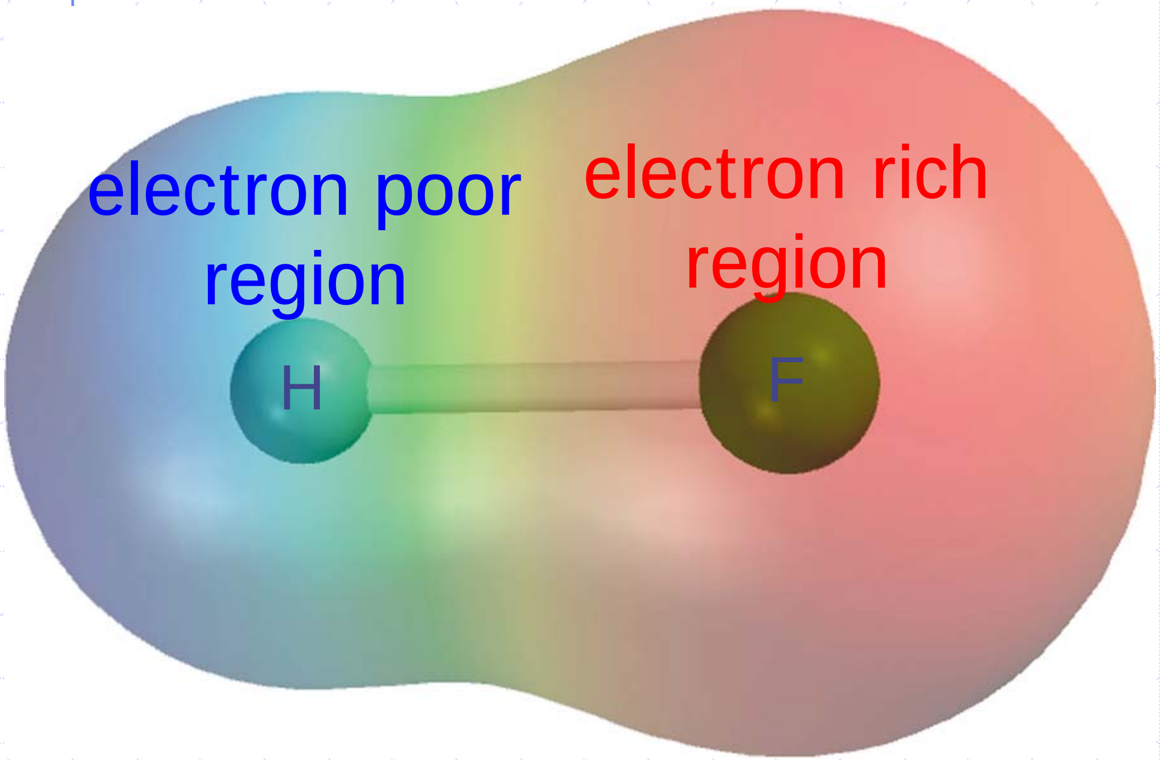
Determination of Bond Type

- <u>Rough</u> range difference in electronegativity
  - 0 - 0.4 : Non-Polar Covalent
    - Even sharing of electrons within a bond
  - 0.4 - 2.0 : Polar Covalent
    - Uneven sharing of electrons within a bo
  - 2.0 – 4.0 : Ionic
    - Stealing or transfer of electrons





Polar or Non-Polar?



e^- poor e^- rich

H—F

∂^+ ∂^-

Classify the following bonds as ionic, polar covalent, or non-polar covalent:

Cs – Cl – 3.0 – 0.8 = 2.2 Ionic

H – S – 2.5 – 2.1 = 0.4 Polar Covalent

N – N – 3.0 – 3.0 = 0 NP Covalent

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Cs 0.8	Ba 0.9	La* 1.1	Hf 1.3	Ta 1.5	W 2.4	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.8	Bi 1.9	Po 2.0	At 2.2
Fr 0.7	Ra 0.9	Ac† 1.1														

below 1.0

1.0–1.4

1.5–1.9

2.0–2.4

2.5–2.9

3.0–4.0

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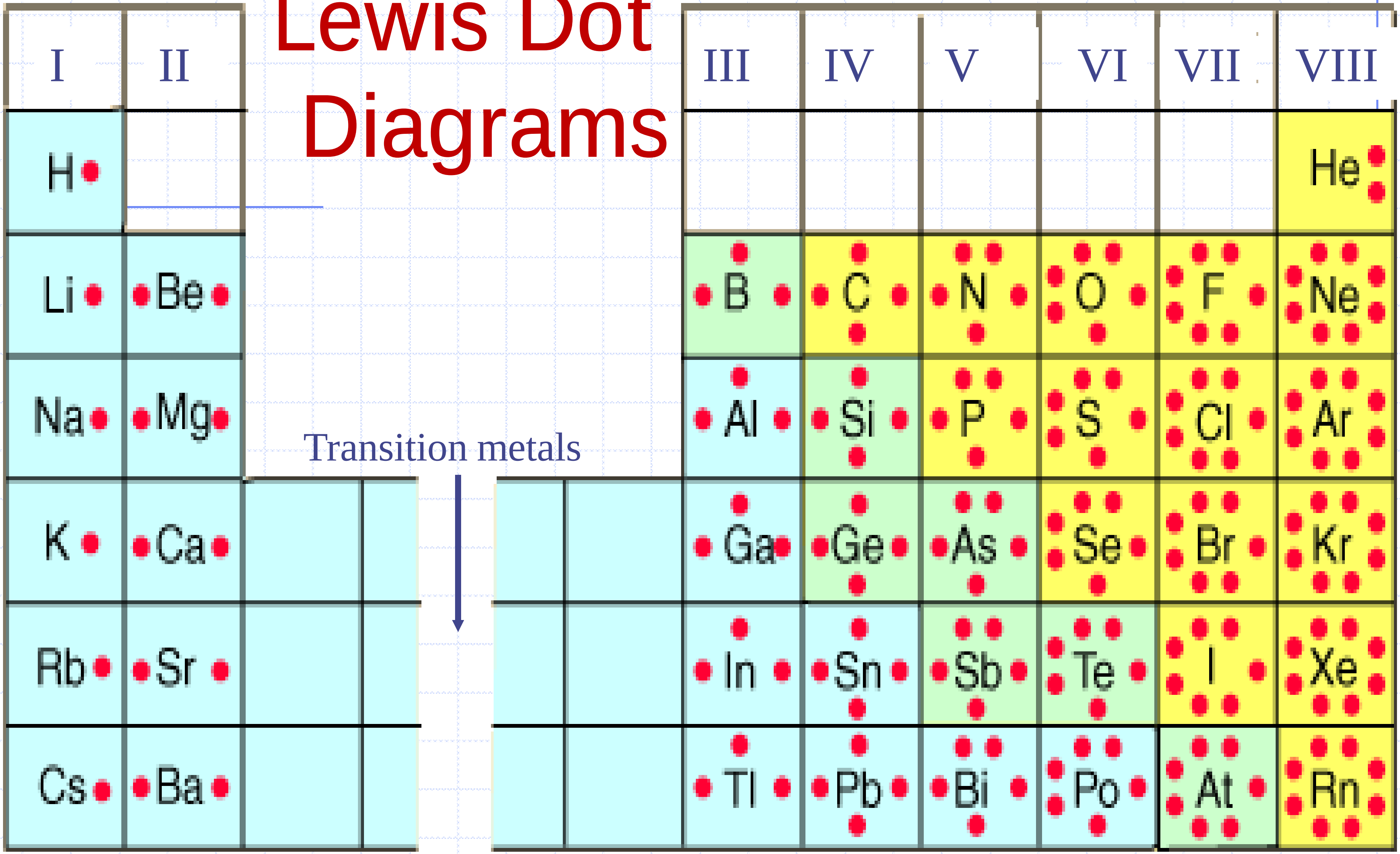
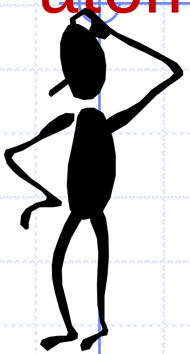
Lewis Dot Diagrams



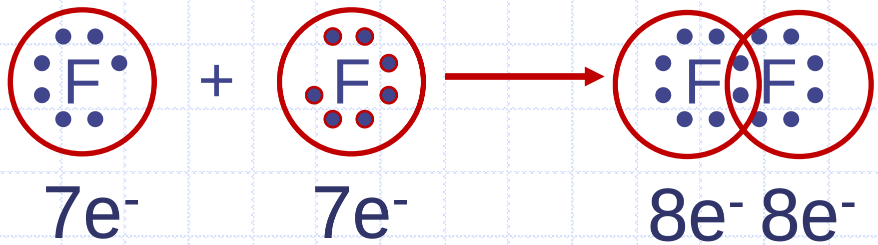
- Lewis Dot Diagrams are used in both ionic and covalent bonding

Covalent (Molecular) Bonding

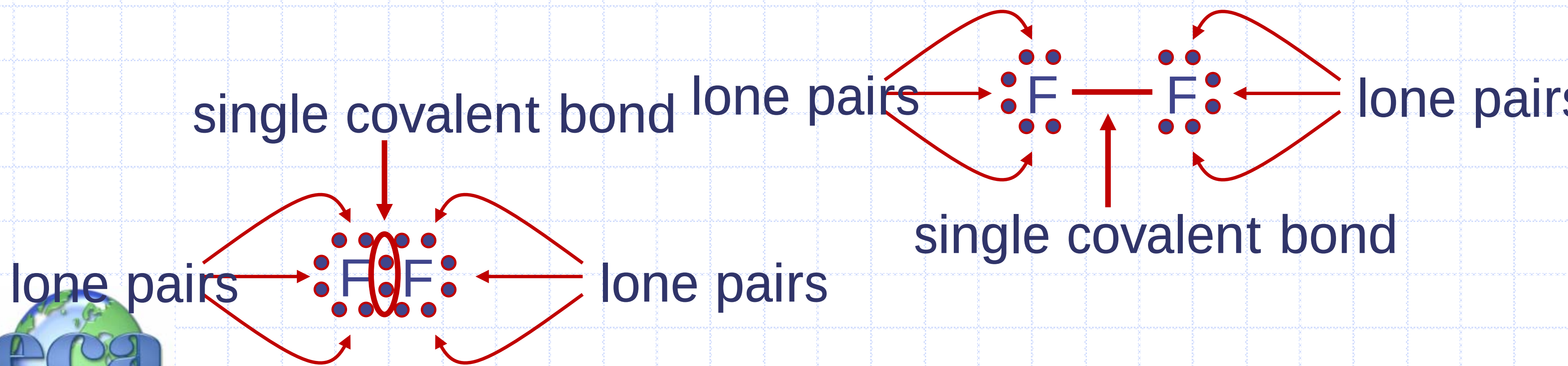
A ***covalent/molecular bond*** is a chemical bond in which two or more electrons are shared by two atoms.



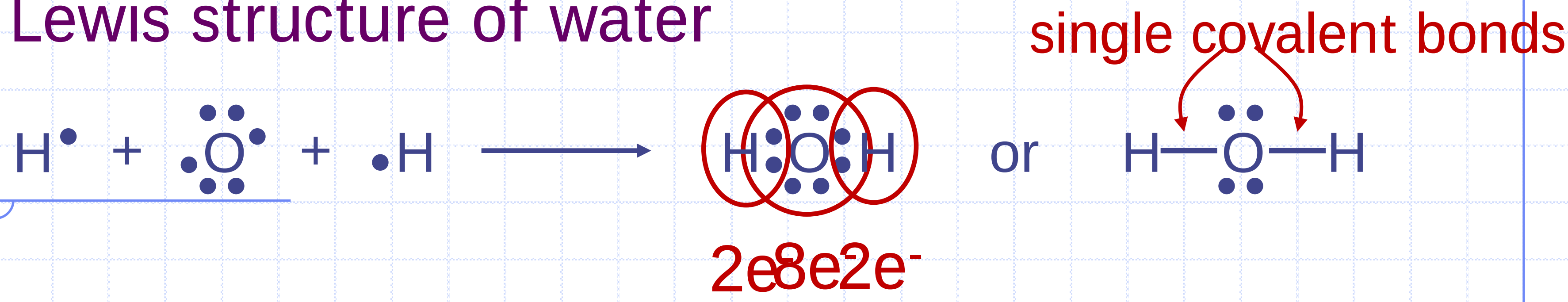
Why should two atoms share electrons?



Lewis structure of F_2

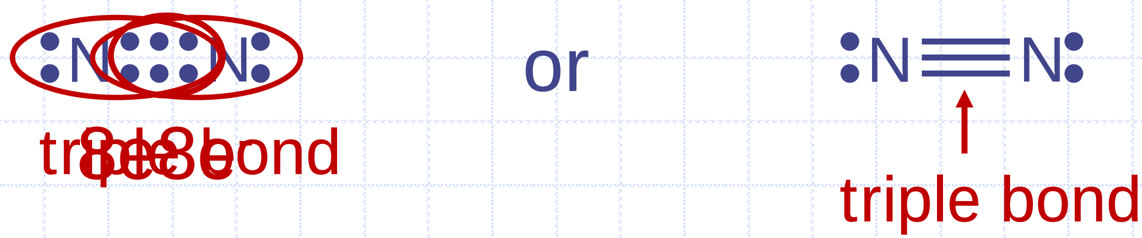


Lewis structure of water



Double bond – two atoms share two pairs of electron

Triple bond – two atoms share three pairs of electron



- Explain intra/inter molecular bonding, the difference between covalent/ionic bonds, how you determine bonding type, and types of bonds:

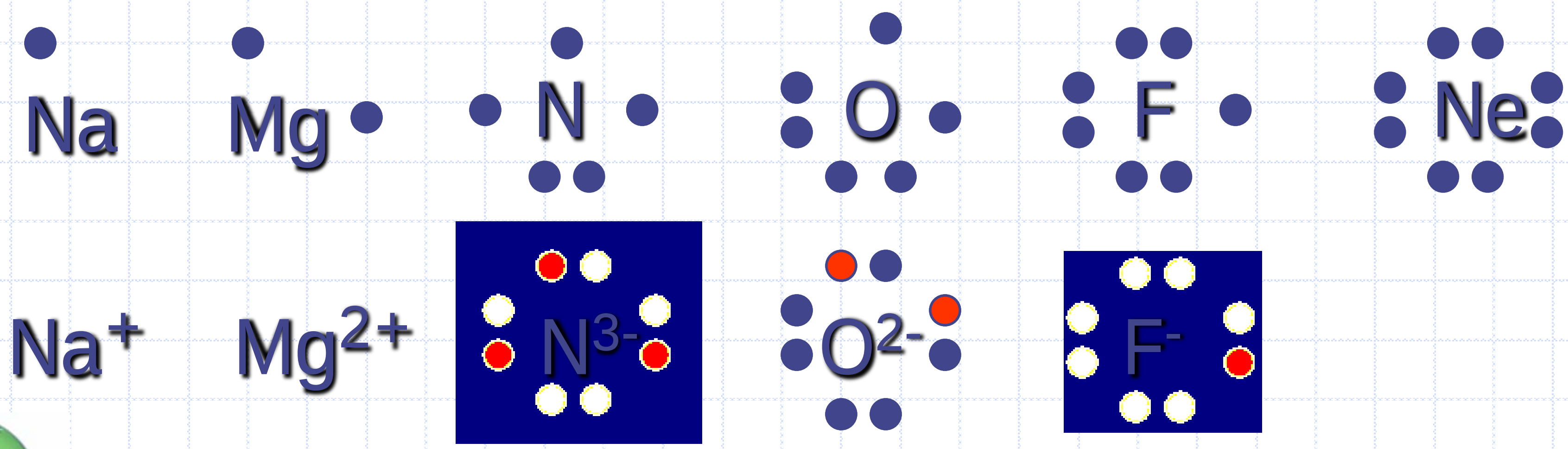
Ionic Bonding

Ions

- Ions form when atoms lose or gain electrons.

Atoms with few valence electrons tend to lose them to form cations.

Atoms with many valence electrons tend to gain electrons to form anions



Cations

Anions

Ionic Bonding

Ionic bonds result from the attractions between positive and negative ions.

Ionic bonding involves 3 aspects:

1. loss of an electron(s) by one element,
2. gain of electron(s) by a second element,
3. attraction between positive and negative

Stable Octet Rule

- Atoms tend to either gain or lose electrons in their highest energy level to form ions
- Atoms prefer having 8 electrons in their highest energy level

Examples

Na	atom	$1s^2\ 2s^2\ 2p^6$ **$3s^1$**	One electron extra
Cl	atom	$1s^2\ 2s^2\ 2p^6$ **$3s^2$ $3p^5$**	One electron short of a stable octet
Na^+	Ion	$1s^2\ 2s^2\ 2p^6$	Stable octet
Cl^-	Ion	$1s^2\ 2s^2\ 2p^6$ **$3s^2$ $3p^6$**	Stable octet

Positive ions attract negative ions forming ionic bonds.

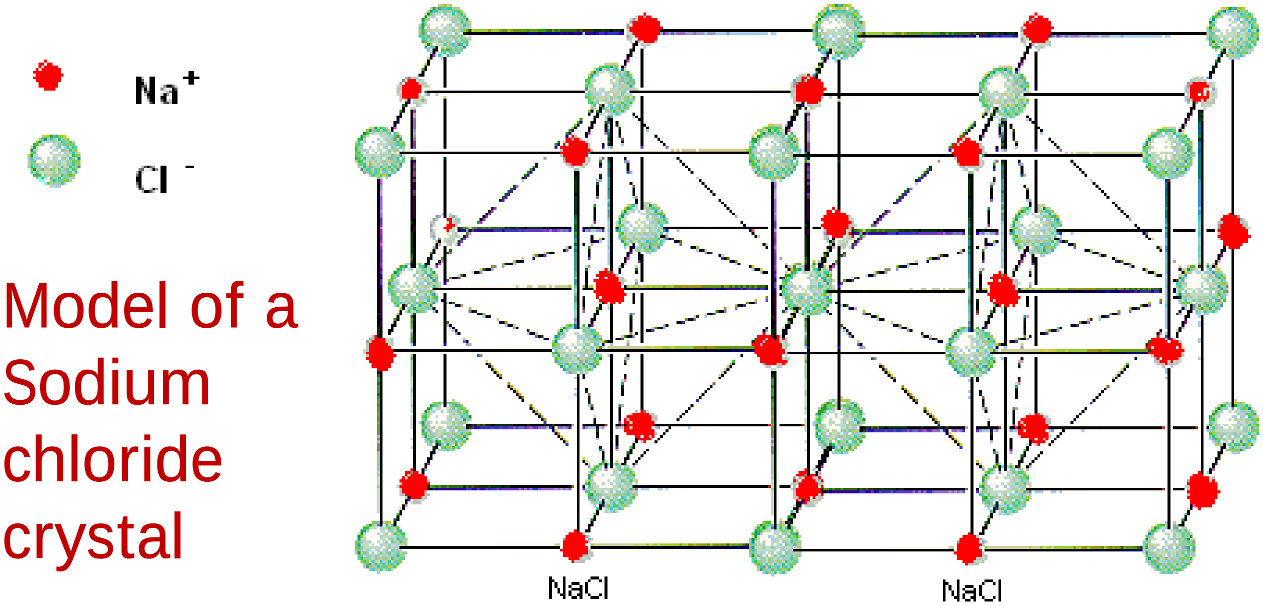
Ionic Bonding

Ionic substances are made of repeating arrays of positive and negative ions.

An ionic crystal lattice

Ionic Bonding

- The array is repeated over and over to form the crystal lattice.

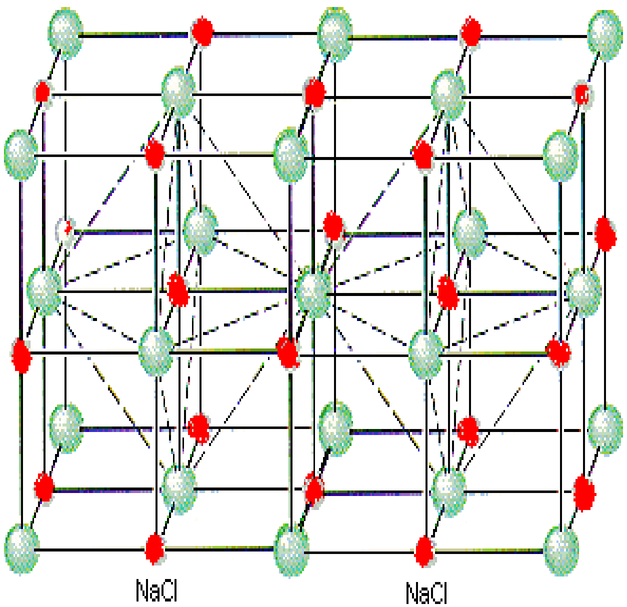


Model of a Sodium chloride crystal

Each Na^{+} ion is surrounded by 6 other Cl^{-} ions. Each Cl^{-} ion is surrounded by 6 other Na^{+} ions

Ionic Bonding

- The shape and form of the crystal lattice depend on several factors:



- The size of the ions
  - The charges of the ions
  - The relative numbers of positive and negative ions

Strength of ionic Bonds

- The strength of an ionic bond is determined by the charges of the ions and the distance between them.
- The larger the charges and the smaller the ions the stronger the bonds will be
- Bond strength then is proportional to

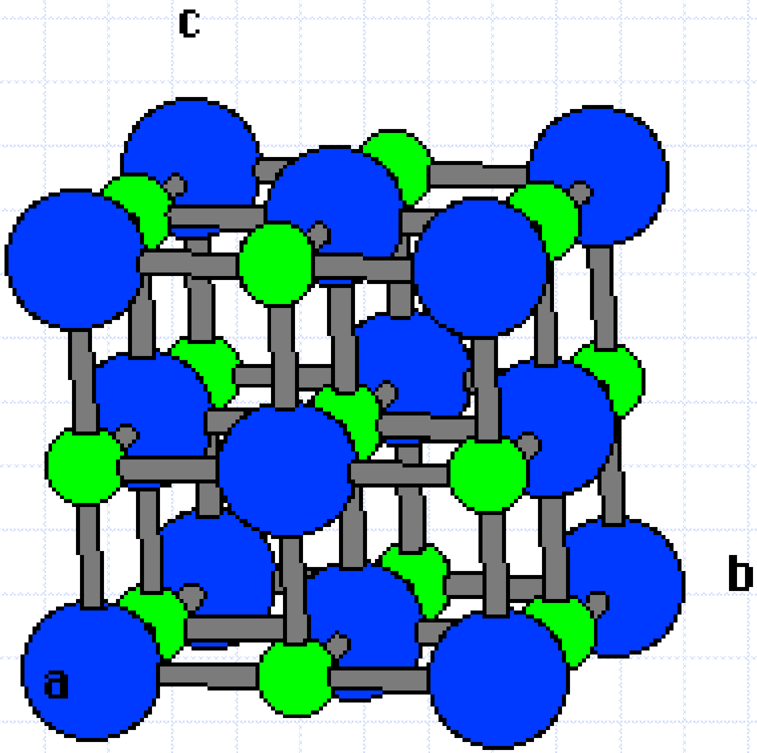
$$\frac{Q1 \times Q\,2}{r^2}$$

Where Q1 and Q2 represent ion charges and r is the sum of the ionic radii.

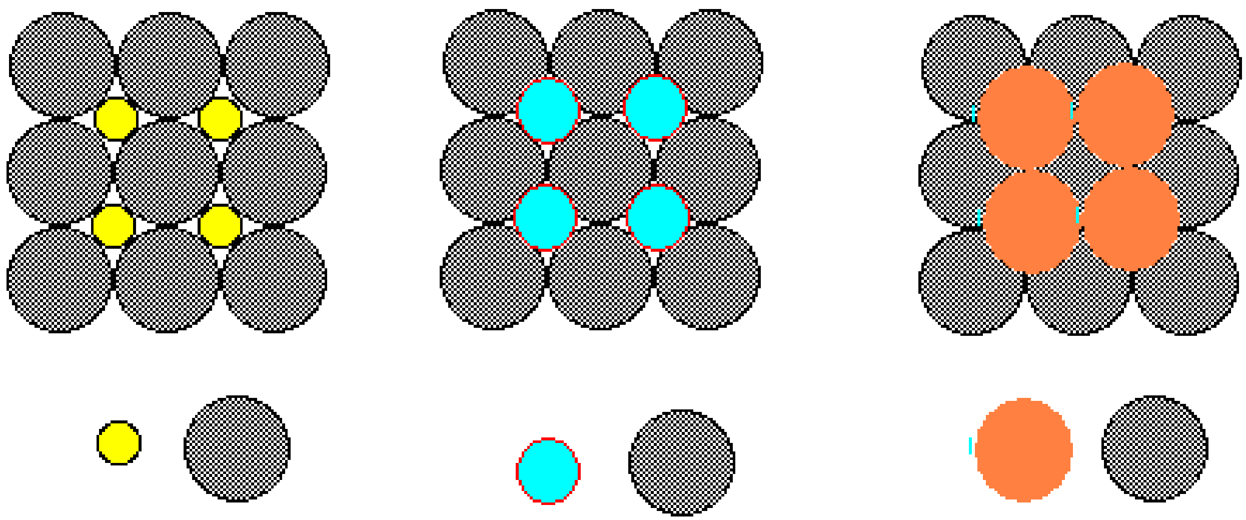
Ionic Structures – Ridig/Hard Sodium Chloride Crystal Lattice

Ionic compounds form solids at ordinary temperatures.

Ionic compounds organize in a characteristic crystal lattice of alternating positive and negative ions.



Ionic Bonding Structure



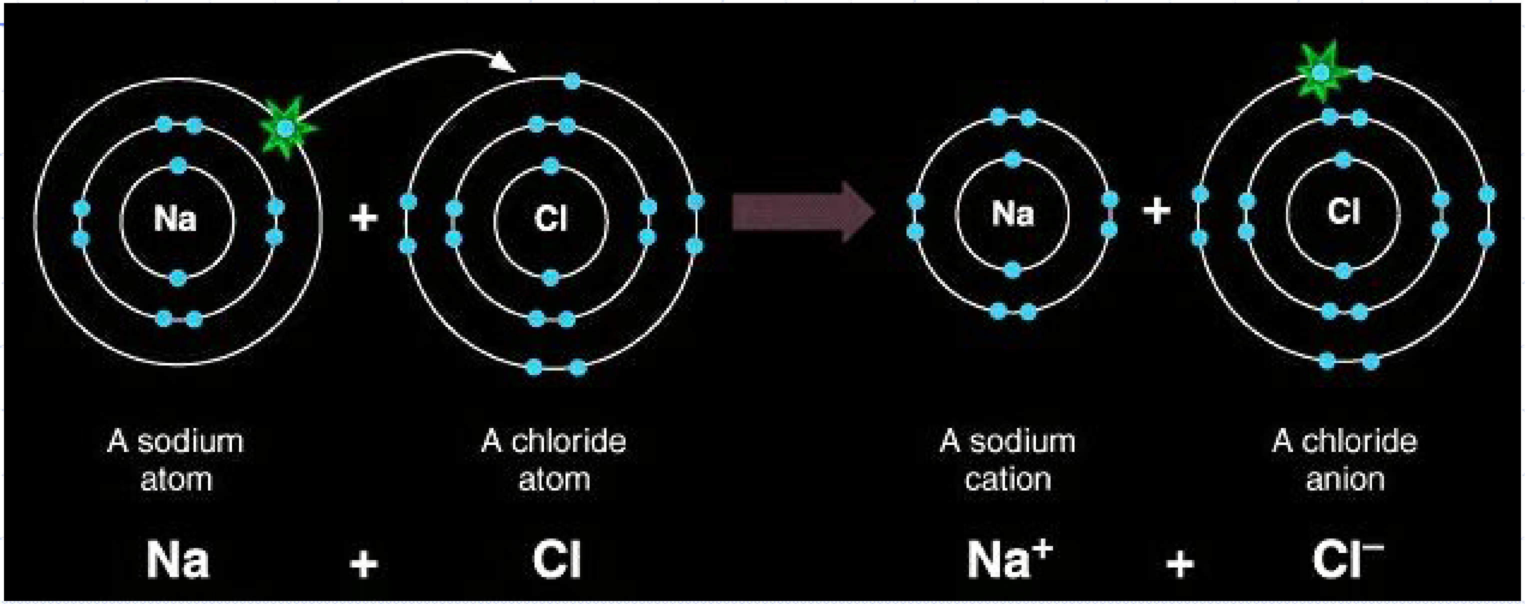
The crystal lattice pattern depends on the ion size and the relative ratio of positive and negative atoms

Ionic Bonding

- Forms between metals and nonmetals
- There is a strong attraction between oppositely charged ions
- Form ionic lattices (network of positively and negatively charged ions)
- Examples: sodium oxide, magnesium chloride, calcium phosphate

Ionic Bonds

- Electrons are transferred



- Electronegativity differences are generally greater than 1.7 or 2.0
- The formation of ionic bonds is always exothermic!

Ionic Bonding: The Formation of Sodium Chloride

- Sodium has 1 valence electron
- Chlorine has 7 valence electrons
- An electron transferred gives each an octet

Na $1s^2 2s^2 2p^6 \mathbf{3s^1}$

Cl $1s^2 2s^2 2p^6 \mathbf{3s^2 3p^5}$

Ionic Bonding:
The Formation of Sodium Chloride

This transfer forms **ions, each with a full <u>octet</u> that is stable:**

Na^{+} $1s^2\boxed{2s^2 2p^6}$

Cl^{-} $1s^2 2s^2\boxed{2p^6 \mathbf{3s^2 3p^6}}$

Ionic Bonding –
the transfer of electrons

[He] [Ne]

$Li + F \longrightarrow Li^{+}F^{-}$

$1s^2 2s^1$ $1s^2 2s^2 2p^5$ $1s^2$ $1s^2 2s^2 2p^6$

$Li \longrightarrow Li^{+} + e^{-}$

$e^{-} + F \longrightarrow F^{-}$

$Li^{+} + F^{-} \longrightarrow Li^{+}F^{-}$

Cations	Name
H^{+}	Hydrogen
Li^{+}	Lithium
Na^{+}	Sodium
K^{+}	Potassium
Mg^{2+}	Magnesium
Ca^{2+}	Calcium
Ba^{2+}	Barium
Al^{3+}	Aluminum

Anions	Name
O^{2-}	Oxide
F^{-}	Fluoride
Cl^{-}	Chloride
Br^{-}	Bromide
N^{3-}	Nitride
I^{-}	Iodide
S^{2-}	Sulfide
P^{3-}	Phosphide

Cations (M)

Anions (NM's)

Writing Ionic Compound Formulas

Example: Magnesium sulfide

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion.

4. Write the formula without charges

$Mg^{2+}S^{2-}$

balanced!

MgS

Writing Ionic Compound Formulas

Example: Potassium Oxide

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion.

4. Write the formula without charges

K^{+} O^{2-}

2 1

Not balanced!

K_2O

Writing Ionic Compound Formulas

Example: Beryllium Nitride

1. Write the formulas for the cation and anion, including CHARGES!

2. Check to see if charges are balanced.

3. Balance charges , if necessary, using subscripts. Use parentheses if you need more than one of a polyatomic ion.

4. Write the formula without charges

$Be^{2+} N^{3-}$

3 2

Not balanced!

Be_3N_2

Properties of Ionic Compounds

Structure:	Crystalline solids
Melting point:	Generally high
Boiling Point:	Generally high
Electrical Conductivity:	Excellent conductors, molten and aqueous
Solubility in water:	Generally soluble

Properties of Molecular/Covalent Compounds

Structure:	Waxy and soft
Melting point:	Relatively low
Boiling Point:	Relatively low
Electrical Conductivity:	Poor conductors in molten and solid state
Solubility in water:	Generally insoluble